T-992 Diamond and 3-D Detector tests at FTBF

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ALL-EXPERIMENTERS' MEETING

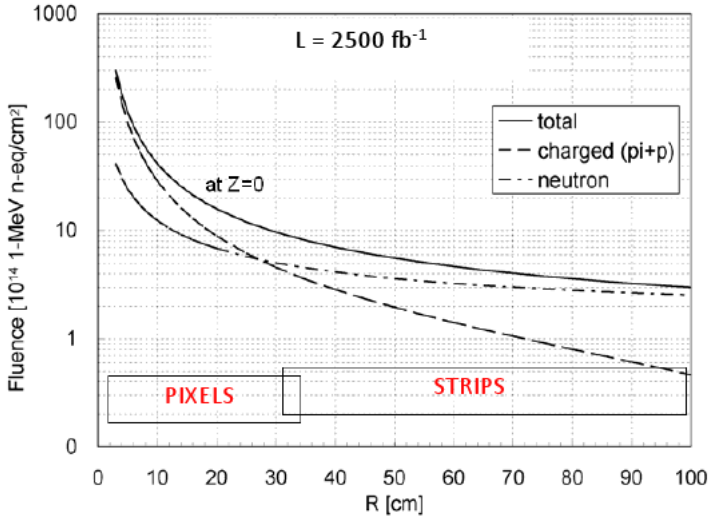
November 14, 2011

Particle Fluence at SLHC

SLHC Upgrade @ $\mathcal{L} = 10^{35}\text{cm}^{-2}\text{s}^{-1}$

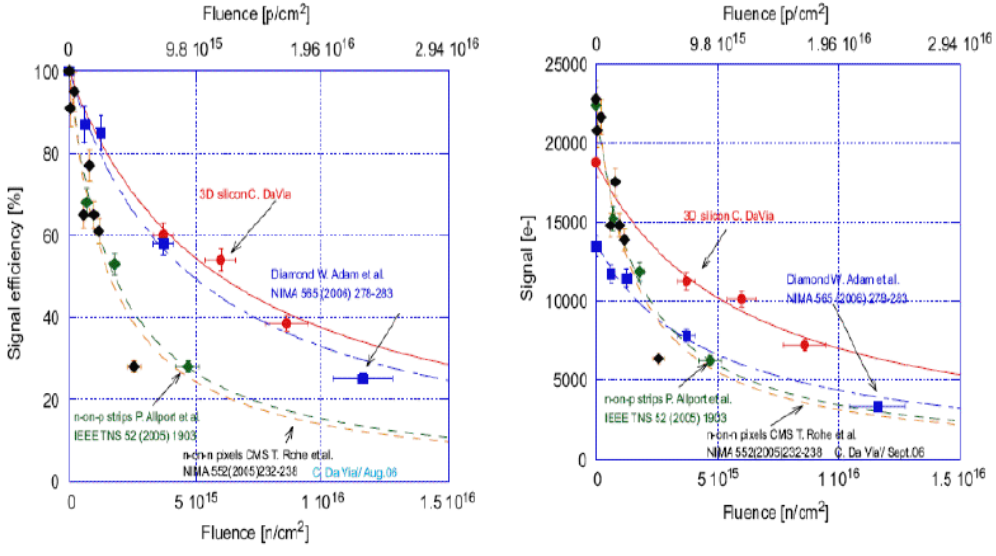
$\rightarrow$ L = 2500 fb^{-1} after 5 years

At R = 5 cm the radiation fluence will be around 10^{16}n-eq/cm^2!!



Being so close to the IP, the Pixel Detector requires an

excellent radiation hardness



C. Da Viá et al. / Nuclear Instruments and Methods in Physics Research A 587 (2008) 243–249

Test Beam Goal

- our goal is to test the candidates for the SLHC upgrade before and after irradiation to compare the performances and understand if we have a technology capable of withstanding the enormous fluences

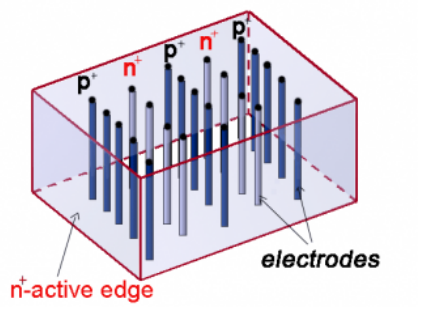
- efforts has been focused on two different sensor types:
  - **3D Silicon sensors**
  - **Diamond sensors**

- all the different sensors have been tested using the same Read Out Chip (ROC) in order to have a fair comparison between all candidates

3D Silicon & Diamond Sensors

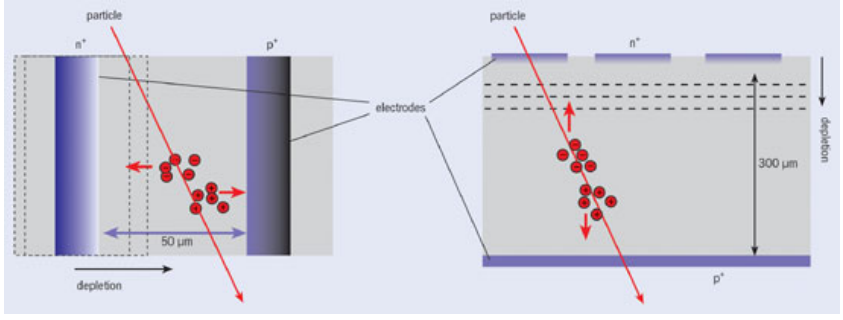
3D Sensors

- first proposed by Sherwood Parker of the University of Hawaii and colleagues in 1995
- p^+ and n^+ electrodes are arrays of columns that penetrate through the silicon bulk



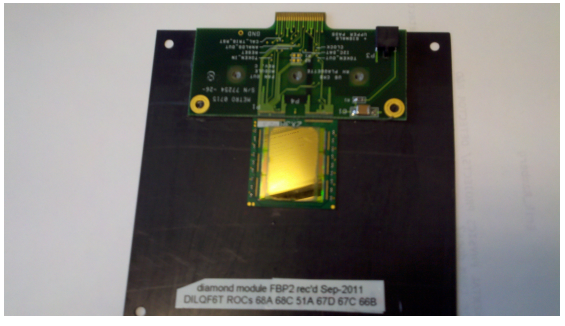
lateral depletion: good for rad-hard

- shorter collection path
- lower full-depletion voltage
- less carrier trapping
- faster charge collection



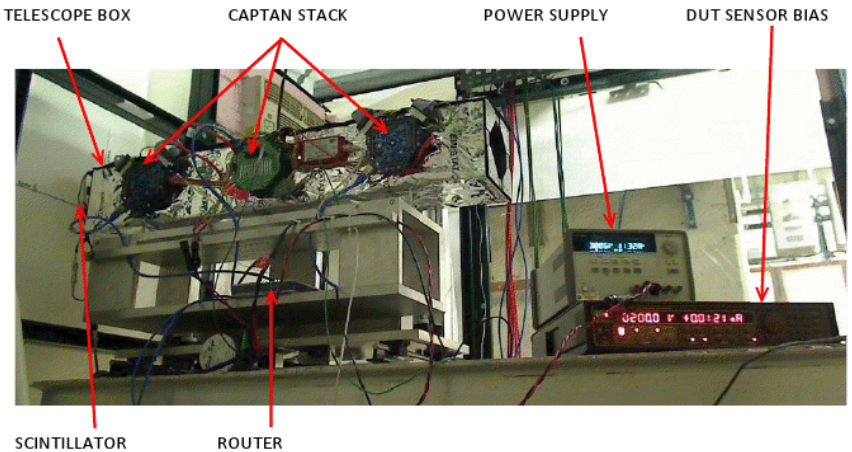
Diamond sensor - intrinsically rad-hard

- high bandgap and high displacement energy
- fast charge collection
- absence of thermally generated leakage current

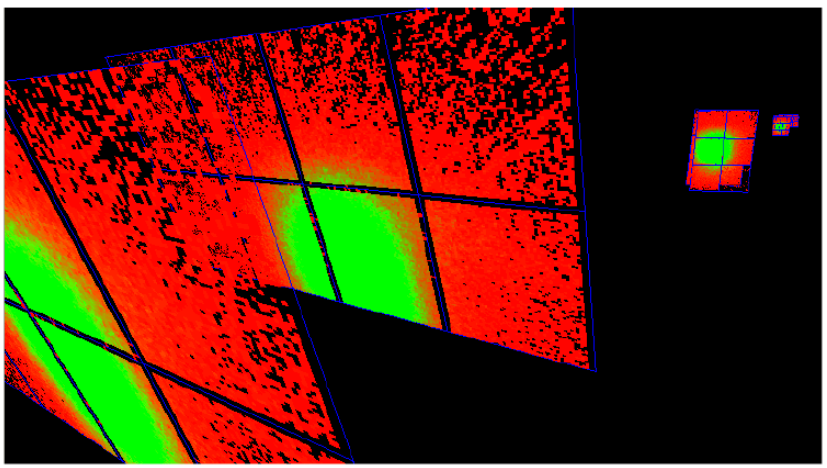


Setup

- Telescope with 8 silicon planar pixel sensors (4 upstream and 4 downstream) with 2 Detectors Under Test (DUTs) in the middle
- Data acquisition with CAPTAN system



- Our software allowed us to check almost real time the data quality



Collaboration

- Many different institutions and collaborators for the CMS pixel upgrade
  - Fermilab
    S. Kwan, A. Prosser, L. Uplegger, R. Rivera, J. Andresen, J. Chramowicz, P. Tan, C. Lei, F. Yang
  - Purdue
    E. Alagoz, O. Koybasi, G. Bolla, D. Bortoletto, M. Bubna, A. Krzywda, K. Arndt
  - Colorado
    M. Dinardo, S. Wagner, J. Cumalat, F. Jensen
  - Texas A&M
    I. Osipenkov
  - Milano
    L. Moroni, D. Menasce, S. Terzo, J. Ngadiuba
  - Torino
    M. Obertino, A. Solano
  - Buffalo
    A. Kumar, R. Brosius
  - IHPC Strasbourg
    J. M. Brom

Test beam preliminary results

- A large number of detectors has been tested on beam and for each of them several scans has been made
  - threshold scan
  - bias scan
  - angle scan
- Preliminary studies has been made just on few runs
  - Resolution
  - Efficiency
  - Charge

These are just preliminary studies

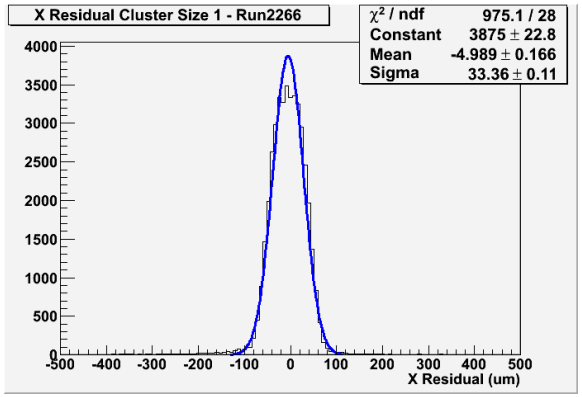
$\Downarrow$

Work in progress!!

3D sensor resolution - Preliminary

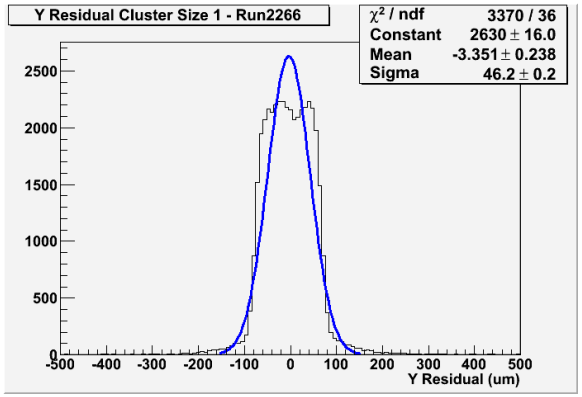
X Residuals Cluster Size 1

$\sigma = 33.36\ \mu$m



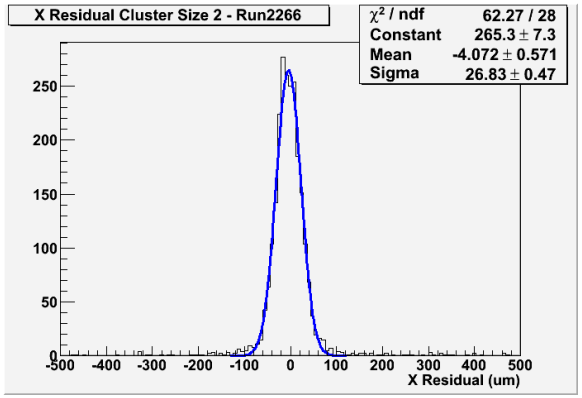
Y Residuals Cluster Size 1

$\sigma = 46.2\ \mu$m



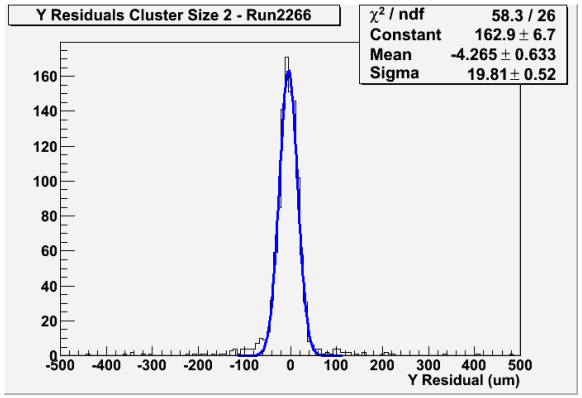
X Residuals Cluster Size 2

$\sigma = 26.83\ \mu$m



Y Residuals Cluster Size 2

$\sigma = 19.81\ \mu$m



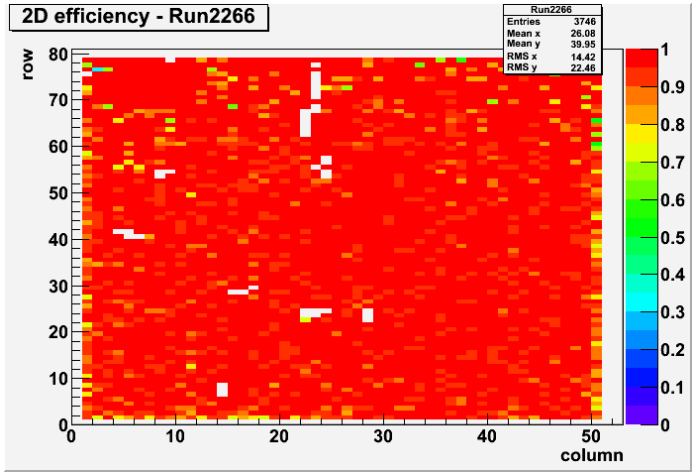
Residuals are not yet optimized but already in good agreement with expectations

3D sensor efficiency - Preliminary

CNM sensor

produced at
Centro National de
Microelectronica
(Barcelona, Spain)

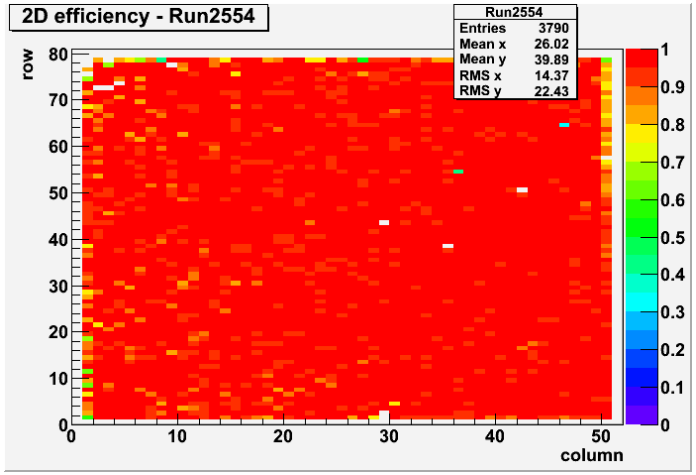
Efficiency = 97.3%



FBK sensor

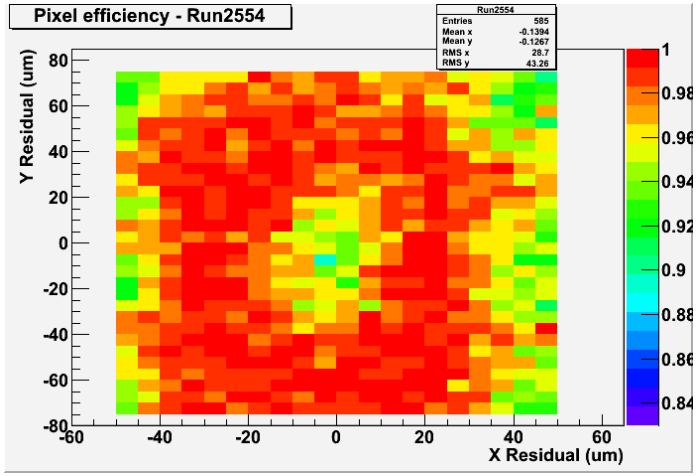
produced at
Fondazione Bruno Kessler
(Trento, Italy)

Efficiency = 97.6%

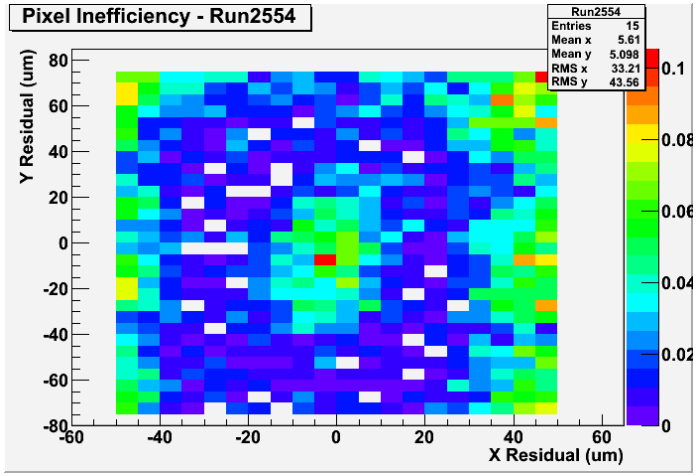


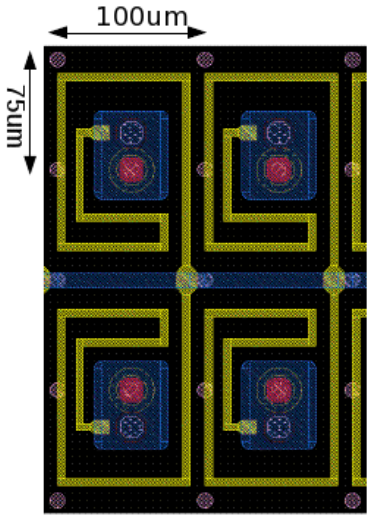
3D cell efficiency - Preliminary

Cell efficiency



Cell inefficiency



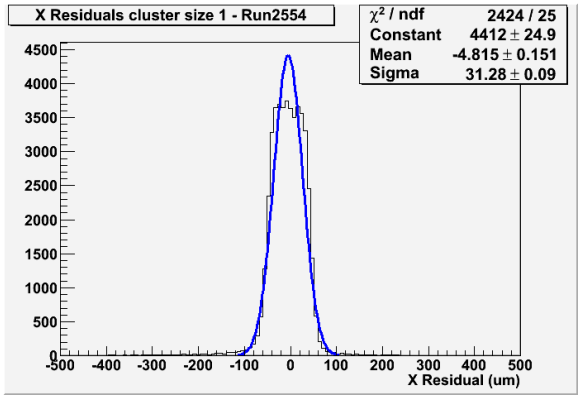


- most of the inefficiency is due to particles passing through the p^+ and n^+ electrodes
- but part of this effect is also due to the fact that both FBK and CNM are double-sided with about 30μm from the edge for each electrode and so there's a slight distortion of the field near the edge

10^{14}n-eq/cm^2 Irradiated FBK resolution - Preliminary

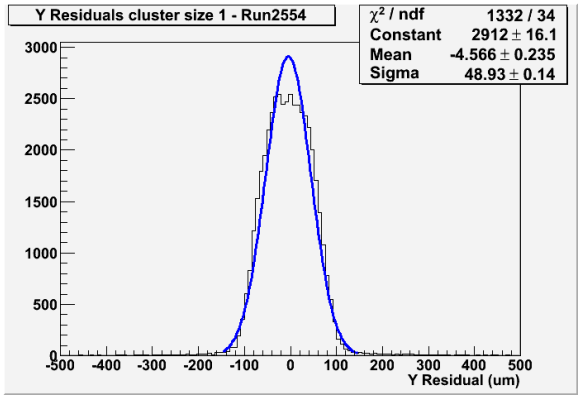
X Residuals Cluster Size 1

$\sigma = 31.28\ \mu$m



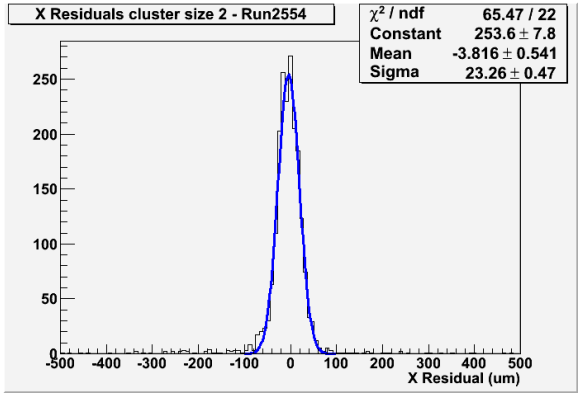
Y Residuals Cluster Size 1

$\sigma = 48.93\ \mu$m



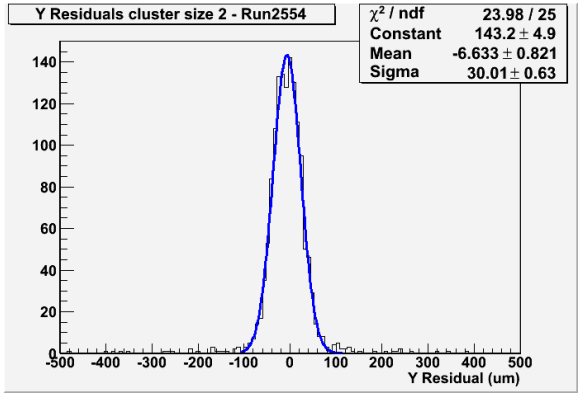
X Residuals Cluster Size 2

$\sigma = 23.26\ \mu$m



Y Residuals Cluster Size 2

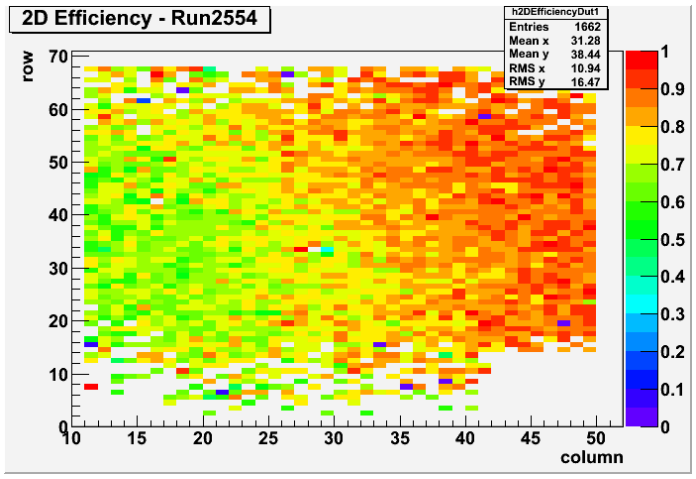
$\sigma = 30.01\ \mu$m

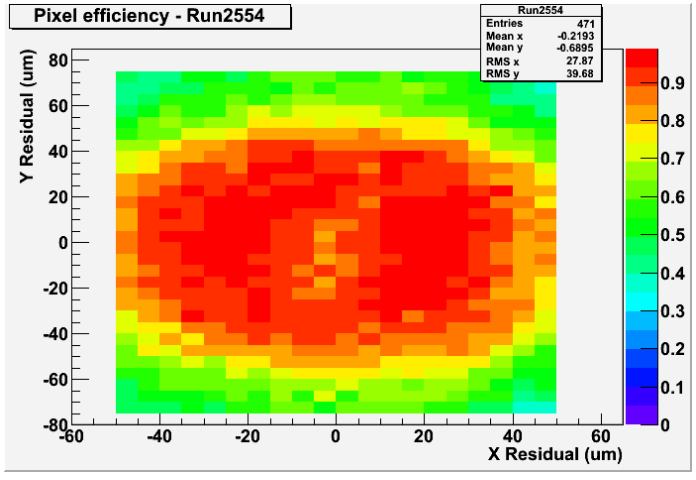


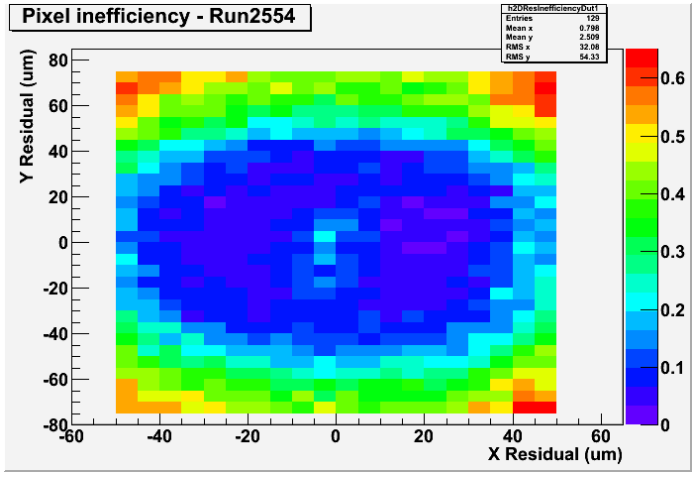
Also for the irradiated we dont't see a particular degradation of the resolution

10^{14}n-eq/cm^2 Irradiated FBK efficiency - Preliminary

Efficiency = 77.8%



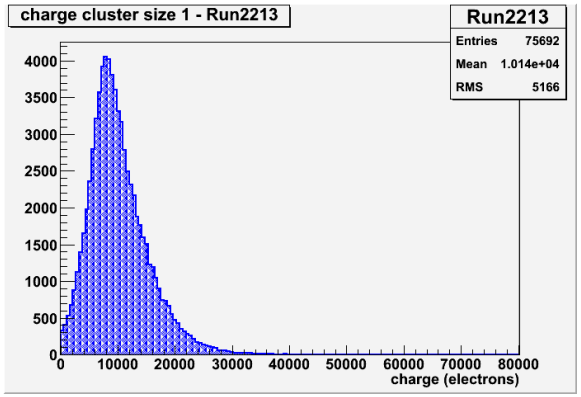


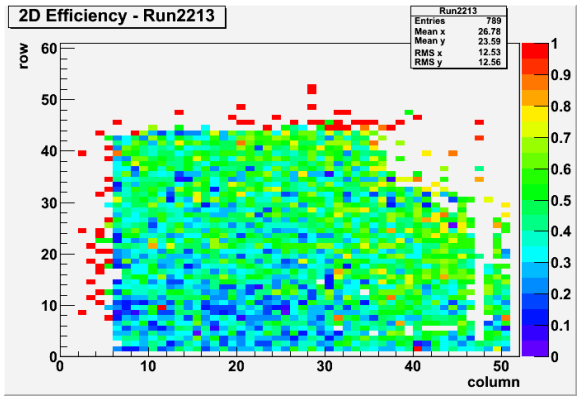


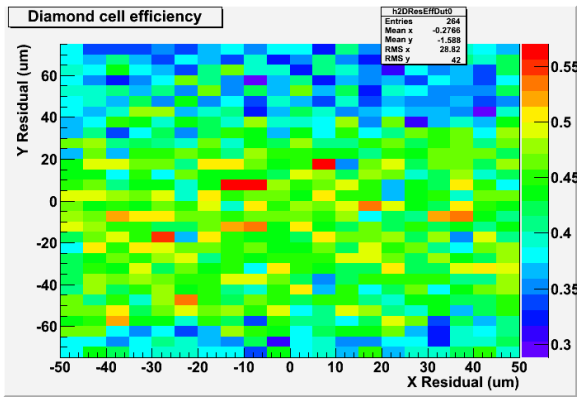
- inefficiency due to particles passing through the electrodes
- but clear effects caused also by a too low field applied (bias = 15V)

→ need to increase the bias voltage to obtain better efficiency results

Diamond efficiency - Preliminary







- cause of the higher bandgap the charge released by particles is about less than half of what we get with our silicon detectors
- since we're using the same CMS ROC optimized for silicon planar design it is important to optimize correctly its registers to match the diamond requirements
- we believe we operated the detector with a threshold too high

⇓

Efficiency = 43.4%

for these reasons we'll have another test beam run in January exclusively dedicated to diamond sensors

Conclusions and future plans

- we succesfully tested many 3D and diamond detectors
- these preliminary results help us to understand their operational parameters which need to be optimized well to make them work correctly
- for these reasons we'll come back to the test beam in January with few selected detectors
- at the last test beam we were not able to test the irradiated devices because after the irradiation none of them worked so this time we irradiated them only up to 10^{14}n-eq/cm^2
  - ◇ we will irradiate them much more in December and then come back to test them in March
- we have all the tools ready to do the analysis although they still need some improvements